rmed Services Technical Information Agen

AD

19292

OTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA RE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATI OVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS O RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE OVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE AID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHE ERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTU SE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO

CONFIDENTIAL

he following ESPIONAGE NOTICE can be disregarded unless this document
plainly marked RESTRICTED, CONFIDENTIAL, or SECRET.

OTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE
ATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING
F THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794.
HE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN
NY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

CONFIDENTIAL

NAVORD REPORT 2839

COPY

CASE GUN PROPELLANT IGNITION

10 JUNE 1953

U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

CONFIDENTIAL

SECURITY INFORMATION

CASE GUN PROPELLANT IGNITION

Prepared by:

R. D. Cool and L. F. Gowen

ABSTRACT: Previous studies at the Naval Ordnance Laboratory indicated that pyrotechnic mixtures having high heats of reaction and yielding high percentages of solids on ignition are more effective than black powder in igniting propellants. Ignition effectiveness is based on the minimum quantities of the various compositions required to ignite the propellants. This report covers closed bomb studies of the ignition of pyro, Cordite-N and two "cool" picrite (1950°K) propellants. Test results show that the relative ease of ignition of the different types of propellants varies with the composition of the ignition mixture and may even be reversed by using different mixtures. Experimental compositions containing boron-potassium perchlorate, magnesium-potassium perchlorate, zirconium-potassium perchlorate, zirconium-potassium perchlorate-lead dioxide, and zirconium-nickel alloy-potassium perchlorate-lead dioxide, proved to be superior to black powder in igniting the four propellants tested. In addition to the ignition studies, the mixtures were investigated to further determine their suitability for use in gun primers. Although the mixtures are more sensitive than black powder to impact, it is believed that the mixtures could be safely used in gun primers. All of the mixtures except two were found compatible with brass and steel. None of the mixtures ignited when subjected to temperatures of the order of 415°C for a period of two minutes.

It is concluded that many of the mixtures studied show considerable promise as substitutes for black powder in gun primers.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVORD Report 2839 | 10 June 1953

This report presents data and results obtained by the Laboratory in connection with the Case Gun Ignition task, in which a study is being made of ignition systems for various types of propellants. The phase of the task covered in this report concerns the search for igniter compositions that will more satisfactorily ignite cool propellants than black powder. This study was authorized by the Bureau of Ordnance Directive NOL-Re2a-184-1-52. The information may be useful to activities interested in gun primer design or propellant ignition.

EDWARD L. WOODYARD
Captain, USN
Commander

D. S. Muzzey Jr.

D. S. MUZZEY, JR.
By direction

REFERENCES

(a) NAVORD Report 1578, "Studies of Propellant Ignition by Pyrotechnic Mixtures" - R. D. Cool, 18 Dec 1950

(b) NAVORD Report 2321, "Case Gun Ignition Studies" - L. Gowen and R. Dwiggins, 13 Jun 1952

(c) NAVORD Report 2213, "An Investigation of Desensitizing Agents for Pyrotechnic Mixtures" - R. D. Cool, 2 Jan 1952

(d) NAVORD Report 1503, "Ignition of the Cool Propellant EX6627 (1900°K) by Hot Solid Bodies" - G. B. Butters, 24 Nov 1950

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

CASE GUN IGNITION

INTRODUCTION

1. Gun firing data show that the system used to ignite the propellant affects the gun's interior ballistics. The trend toward higher muzzle velocities and rapid rates of fire has necessitated the development of new propellant formulations. The new propellants have accentuated the need for ignition systems that will provide the desired interior ballistics. In an effort to develop better igniters, the Laboratory has conducted studies of igniter compositions that have a higher calorific value and produce combustion products having a greater percentage of solid residue than black powder. As indicated in references (a) and (b), these mixtures were found more efficient than black powder in igniting propellants. This Navord covers later investigations using oxidants other than those previously reported.

Apparatus and Procedure

2. Ignition tests were made in a heavy brass bomb shown in Figure 1. The bomb has a cylindrical cavity 64mm in diameter and 63mm in length (approximately 203ml volume). A threaded opening in the bottom of the bomb permits insertion directly under the propellant grain holder of a shortened Mk 39 Gun Primer stock containing the ignition element and pyrotechnic charge.

3. Components of the mixture were carefully weighed on a Torsion Balance to the nearest gram and mixed on bond paper with a spatula. Information concerning the chemicals used is presented in Table I. Charges of the mixtures were weighed on the Torsion Balance or an analytical balance and placed loose in the cup of the ignition element. The propellant grain was held vertically in the bomb with the lower end of the grain about 18mm above the edge of the primer cup. After closing the bomb the ignition element was connected in series with a 375-watt bulb and fired with a 115-volt D.C. source.

4. Each fuel-oxidant combination was tested in varying amounts and in varying ratios of fuel to oxidant. Primer Electric, Mk 39 ignition elements with lead styphnate buttered over the bridge wire were used to ignite charges of 0.1g or larger. Tests showed that a lead styphnate-buttered element alone would not ignite the propellant grain. Ignition charges less than 0.1g were widely dispersed by the lead styphnate, producing erratic results. Therefore, charges less than 0.1g were placed directly on the bridge wire.

5. The minimum amount of black powder required to ignite the propellants was first determined because only ignition compositions that proved more effective than black powder were to be considered. Ignition effectiveness is based on the minimum amount of the composition required to ignite the propellant. These data fixed the maximum amount of experimental ignition composition to be investigated. A minimum charge of 0.4g of 3FG black powder initiated with lead styphnate was required to ignite an IHCD-24 grain (2550°K) in the bomb. Approximately the same charge was required to ignite four smaller EX-6706 grains (1950°K) clustered together in the grain holder. The four-tenths gram of 3FG black powder would not ignite an SPCG-9149 grain (2450°K) the same size as the IHCD-24 grains. Therefore, quantities of ignition composition not exceeding 0.4g were used with the lead styphnate initiator. When the buttered lead styphnate was omitted and the ignition mixture placed directly on the bridge wire, 0.32g of 3FG black powder was required to ignite an IHCD-24 pellet and 0.31g to ignite a cluster of seven smaller HKPC-1 grains (1950°K). Therefore, charges of experimental ignition composition not exceeding 0.30g were used when the lead styphnate was omitted. If the mixture was not more effective than black powder in igniting IHCD-24 grains (the most readily ignitible propellant investigated), tests usually were not made with the other propellants. A complete description of the propellants used is presented in Table II.

6. In order to evaluate more fully the experimental igniter compositions as substitutes for black powder in gun primers, other tests were conducted on the most promising mixtures. Impact sensitivity tests were made by dropping a 2 kilogram weight on 10mg of composition pressed into Mk 102 primer cups. Twenty-five samples were used for each determination of the 50% drop height. Further details on the impact sensitivity test procedure will be found in reference (c). A Parr-Dennis melting-point apparatus and a hot plate equipped with a calibrated thermocouple were used to determine whether the mixtures ignited when subjected to temperatures up to 415°C for a period of two minutes. Tests were conducted to determine the compatibility of the ignition mixtures with steel, brass and paper components of gun primers. These tests were conducted at 160°F and 83% relative humidity in a desiccator containing a saturated solution of sodium carbonate monohydrate in contact with an excess of the solid phase.

7. Firing tests at low temperatures were made in a test cabinet kept at -65°F by dry ice and a thermostatically controlled blower. The closed bomb containing the propellant, the pyrotechnic charge and connections for ignition was placed in the

test cabinet for 15 hours. The charge was then fired without opening the cabinet. After firing, the bomb was removed from the cabinet and permitted to warm to room temperature. All condensed moisture was removed before a new charge was introduced.

Results

8. Ignition test results obtained with 3FG black powder and the experimental igniter compositions are given in Tables III through XV. Data obtained with IHCD-24 and SPCG-9149 propellants may be directly compared, but data obtained with the other two propellants studied (EX-6706 and HKPC-1) cannot be directly compared because of the market difference in physical size of the grains. The igniting ability of the black powder and the experimental ignition composition were compared for each specific propellant. The minimum quantities of ignition mixture required for the ignition of each propellant were used as basis for comparison.

9. The ignition test results show that a number of compositions are superior to black powder in igniting each of the four propellants tested. In Table XVI black powder and the experimental compositions are listed in the order of increasing amounts required to ignite IHCD-24 grains when the primer wire alone was used to ignite the experimental compositions. Table XVII gives corresponding data for tests in which lead styphnate was used together with the bridge wire to ignite the mixtures. The data given in Tables XVI and XVII show that the relative ease of ignition of the various types of propellant varies with the composition of the ignition mixture and may even be reversed by using different mixtures.

10. Data in Tables VI, IX, XII and XIII show that mixtures of titanium-potassium perchlorate and zirconium-potassium perchlorate are more effective than similar titanium-sodium nitrate and zirconium-sodium nitrate mixtures in the ignition of IHCD-24 propellant grains. This would be expected from the thermal properties (reference (a)) of the materials.

11. Results of impact sensitivity tests on six mixtures are given in Table XVIII. The mixtures are more sensitive than black powder to impact. However, it is believed that the sensitivity will not preclude the use of these mixtures in gun primers.

12. Magnesium-potassium perchlorate (1:2), zirconium-nickel alloy-potassium perchlorate (1:1), boron-potassium perchlorate (1:3,1:4,1:5), and zirconium (200-325 mesh)-potassium

perchlorate (1:1) mixtures did not ignite when subjected to a temperature of 415°C for a two-minute interval. Tests at temperatures greater than 415°C were considered unnecessary because the material will not be exposed to such extreme conditions in service use.

13. Closed bomb ignition tests at -65°F with Cordite-N were conducted with 3FG black powder and boron-potassium perchlorate (1:5) mixture. Data presented in Table XIX show that 1.20g of black powder were required to ignite a Cordite-N grain whereas only .3g of the experimental mixture was required.

14. Results of compatibility tests made with several promising mixtures on cadmium-plated steel primer tubing, brass primer stocks, and paper primer tube liners are given in Table XX. Serious corrosion of the cadmium plating was caused by the magnesium-potassium perchlorate (1:2) mixture and the zirconium-potassium perchlorate (1:1) mixture. It is interesting to note that the zirconium-potassium perchlorate mixture with a small amount (9%) of lead dioxide present did not corrode the plating. Only the magnesium-potassium perchlorate mixture caused corrosion of the brass plug. All the mixtures caused either a bleaching of the paper or a light brown stain, or both, with the exception of the zirconium-nickel alloy-potassium perchlorate mixture, which left a dark brown stain over the entire contact surface. Black powder will not stand up under the conditions of this test and therefore was not used as a standard.

CONCLUSIONS

15. The following conclusions were drawn from the data and results herein presented:

a. The relative ease of ignition of the different types of propellant varies with the composition of the ignition mixture and may even be reversed by using different mixtures.

b. The experimental igniter compositions studied were found to be more effective igniters than black powder.

c. Fuel-potassium perchlorate mixtures are more effective in igniting propellants than corresponding fuel-sodium nitrate mixtures.

d. None of the more promising igniter mixtures studied will "cook off" below 415°C.

TABLE I

Materials Used

Fuels

Aluminum (Flake) through 100 mesh
Boron (Amorphous, pure, Fisher B-375, Lot No. 502858)
Boron (Amorphous, 82% purity, F. W. Berk & Co., Wood Ridge, N. J.) 325 mesh
Magnesium, atomized through 325 mesh
Sulfur, pulverized
Titanium (98.5% purity, Brush Laboratories Co.). 200-325 mesh
Zirconium (Screened fractions from Sample 388-9, Frankford Arsenal) 100-200, 200-325 mesh
Zirconium (70%) nickel (30%) alloy

Oxidants

Ferric oxide (Bakers C. P. Analyzed Powder, Lot No. 112240)
Lead diozide (Bakers C. P. Analyzed Powder, Lot No. 4943)
Potassium perchlorate (Reagent) 200-325 mesh
Potassium nitrate (Reagent) 200-325 mesh
Sodium nitrate (Reagent) 200-325 mesh

TABLE II

Characteristics of Propellants used in Tests

Composition, wt. %	Pyro-Powder IHCD-24	Cordite N SPCG-9149	EX-6706	HKPC-1
Nitrocellulose	93.42	18.16	20.0	20.34
Nitroglycerine		18.38	8.8	8.73
Diphenylamine	.48			
Nitroguanadine		54.72	60.0	59.80
Centralite		7.03	2.0	
Dibutylphthalate			9.2	
$CaCO_3$		.17		
$PbCO_3$			1.0	0.99
K_2SO_4		1.45		
Carbamite				1.98
Dinitrotoluene + Dibutylphthalate				9.15
(Nitrogen)				13.19
Total volatiles	6.10	.09		
Theoretical flame temp °K	2550	2450	1950	1950
Gun in which used	6"/47	6"/47	3/70	3/70
Length	1"	1"	".45	".35
Diameter	".40	".40	".20	".14

TABLE III

Ignition Tests with 3FG Black Powder

Wt. of 3FG Powder	I	S	E	H
0.70g		+		
0.60		−		
0.50	+(+)(+)	−(+)	+(+)	
0.45	+		+	
0.43	+			
0.42	+		+	
0.41	+++		+	
0.40	−−−++(+)	−(−)	−(−)	(+)
0.35	(+)			(+)
0.33	−−−(+)(+)(−)			(+)
0.32	−−−(−)(−)(+)			
0.31				(+)
0.30	(−)(−)		(−)	(−)
0.20			(−)	(−)
0.10				(−)

Note: Significance of symbols

I	Pyro-Powder IHCD-24 (1 grain)
S	Cordite N SPCG-9149 (1 grain)
E	EX-6706 (4 grains)
H	HKPC-1 (7 grains)
+	The propellant grain ignited and burned completely
+/4	The grain ignited but only the lower quarter burned
−	The grain did not ignite
( )	Indicates that the primer wire was used to ignite the experimental mixture. Symbols without parentheses indicate that lead styphnate was used in the primer.
++	When more than one symbol is included in a space, each symbol represents a separate test.
x	The experimental mixture did not ignite

TABLE IV

Ignition Tests with Mixtures of Boron (pure-Fisher) and Potassium Perchlorate

Ratio B:$KClO_4$	3:1	2:1	1:1		1:2		1:3			
Wt	I	I	I	S	I	S	I	S	E	H
0.40g	+	+	+							
.30	-	+	±		+		+			
.20		-	+	+	∓	+	+	+		
.10			-	-	-	-	+	-	+	
.05							(∓)	(+)		
.04							(+)			
.03							(+/4)	(+)	(+)	(+)
.02								(+)	(+)	(+)
.01								(-)	(-)	(-)

	1:4				1:5			
	I	S	E	H	I	S	E	H
0.40g								
.30								
.20	+	+				+		
.10	+	-	-		+	-	+	
.05	(∓)	(-)	(+)	(+)	(+)	(+)	(+)	
.04	(-)				(+)			
.03	(-)		(+)	(+)	(-)			(+)
.02	(-)		(+)	(+)	(-)	(+)	(+)	(+)
.01			(+)	(-)	(+)	(+)	(-)	(-)

Note: See Table III for meaning of symbols

TABLE V

Ignition Tests with Mixtures of Boron and Sodium Nitrate and Boron, Potassium Nitrate and Sulfur

Ratio	1 Boron (pure-Fisher) / 1 Sodium Nitrate		1 Boron (82%-Berk) / 1 Sodium Nitrate		15 Boron (pure-Fisher) / 7 Sulfur / 75 Potassium Nitrate	
Wt.	I	S	I	S	I	S
0.40g					+	
.30	+				+	+
.20	=	+	+	+	-	-
.10	-	+	(=)	(+)		
.05		-		(+)		
.04						
.03				(+)		
.02						
.01			(-)	(+)		

See Table III for meaning of symbols.

TABLE VI

Ignition Tests with Mixture of Zirconium (100-200 mesh) and Potassium Perchlorate

Ratio $Zr:KClO_4$	3:1	2:1	1:1	1:2	1:3
Wt	I	I	I	I	I
0.40g	+	+	+	+	+
.30	-	+	+	+	+
.20		-	+	+	x
.10			-	+ +	
.05				x $(\bar{x})$	

TABLE VII

Ignition Tests with Mixtures of Zirconium (200-325 mesh) and Potassium Perchlorate

Ratio $Zr:KClO_4$	3:1	2:1	1:1				1:2	1:3
Wt	I	I	I	S	E	H	I	I
0.40	-	+	+	+			+	+
.30		-	+	+			+	+
.20			+	+	+		+	-
.10			+ ∓	-	-		x	
.05			$(\bar{-})$	(-)	(+)			
.04			(-)		(+)			
.03					(-)	(+)		
.02						(-)		
.01						(-)		

Note: See Table III for meaning of symbols.

TABLE VIII

Ignition Tests with Mixtures of Zirconium, (200-325 mesh) Potassium Perchlorate and Lead Dioxide

Ratio $Zr:KClO_4:PbO_2$	10:10:1		10:10:2				10:10:10	
Wt	I	S	I	S	E	H	I	S
0.30							+	
.20	+	+		+	+		-	+
.10	-	-	+	-	-			-
.05			(∓)	(+)				
.04			(-)	(+)		(+)		
.03			-	(+)		(-)		
.02				(+)	(+)			
.01				(-)	(-)			

TABLE IX

Ignition Tests with Mixtures of Zirconium (100-200 mesh) and Sodium Nitrate

Ratio $Zr:NaNO_3$	3:1	2:1	1:1	1:2	1:3
Wt	I	I	I	I	I
				x	
0.40	+	+	($\bar{x}$)	+	x
.30	-	-	-	x	
.20			-		
.10			-		

See Table III for meaning of symbols.

TABLE X

Ignition Tests with Mixtures of Zirconium (70%) - Nickel (30%) Alloy and Potassium Perchlorate

Ratio Alloy:$KClO_4$	3:1	2:1	1:1		1:2				1;3	
Wt	I	I	I	S	I	S	E	H	I	S
0.40g	-	-								
.30	-	-	+		+				+	
.20			+	+	+	+			+	+
.10			(-)	-	+	-	+		+	-
.05					(x)				(x)	
					(x)					
.04										
.03							(x)	(x)		

TABLE XI

Ignition Tests with Mixtures of Zirconium (70%) - Nickel (30%) Alloy and Potassium Perchlorate and Lead Dioxide

Ratio Alloy:$KClO_4$:PbO_2	5:10:1				5:10:2				10:10:2			
Wt	I	S	E	H	I	S	E	H	I	S	E	H
0.20	+	+	+		+	+	+					
.10	-	-	-		-	-	-					
.05	(-)	(+)	(+)	(x)	(-)	(+)	(+)		(-)	(-)	(-)	(-)
				(x)								
.04		(-)	(-)	(-)		(+)	(-)	(+)				(-)
.03		(-)	(-)	(-)		(-)		(-)				(-)

Note: See Table III for meaning of symbols.

TABLE XII

Ignition Tests with Mixtures of Titanium and Potassium Perchlorate

Ratio Ti:$KClO_4$	3:1	2:1	1:1		1:2		1:3	
Wt	I	I	I	S	I	S	I	S
0.40	-	-	+		+		+	
.30			-	+	+		+	
.20				+	+	+	+	+
.10				-	-	-	-	-

TABLE XIII

Ignition Test with Mixtures of Titanium and Sodium Nitrate

Ratio Ti:$NaNO_3$	5:1		4:1		3:1	2:1	1:1	1:2	1:3
Wt	I	S	I	S	I	I	I	I	I
								x	
0.40	+		-	+	-	-	-	x	x
.30	-	-							

Note: 0.4 grams of a Titanium-Lead Dioxide Mixture (1:1) failed to ignite a Pyro grain.

0.4 grams of a Zirconium-Titanium-Ferric Oxide (17:33:50) failed to ignite both pyro and cordite N grains.

Note: See Table III for meaning of symbols.

TABLE XIV

Ignition Tests with Mixtures of Atomized Magnesium and Potassium Perchlorate

Ratio $Mg:KClO_4$	3:1		2:1		1:1		1:2				1:3	
Wt	I	S	I	S	I	S	I	S	E	H	I	S
0.40	+				+		+				+	
.30	+		+	+	+	+	+				+	
.20	-	+	-	+	-	+	+				+	
.10		-		-		+	+	+	+		x	+
								=			+	
.05		-				-	$\overline{(+)}$	(-)	+	(+)	-	x
												x
.04										(+)		
.03							(+)		(+)	(-)		
.02									(-)			
.01							(+)		(-)			
									(-)			

TABLE XV

Ignition Tests with Mixtures of Flake Aluminum and Potassium Perchlorate

Ratio $Al:KClO_4$	3:1	2:1		1:1		1:2		1:3	
Wt	I	I	S	I	S	I	S	I	S
0.40	+								
.30	-	+		+		+		+	
.20		+	+	-	+	+	+	+	+
.10		-	-		-	-	+	-	-
.05							-		

Note: See Table III for meaning of symbols.

TABLE XVI

Minimum Charge Required for Ignition Using Primer Wire Only

Composition	I	S	E	H
Mg-$KClO_4$ 1:2	.01	> .05	.03	.04
B-$KClO_4$ 1:3	.04	.02	.02	.02
B-$KClO_4$ 1:5	.04	.01	.02	.02
B-$KClO_4$ 1:4	.05	> .05	.01	.02
Zr(200-325)-$KClO_4$-PbO_2 10:10:2	.05	.02	.02	.04
Zr(200-325)-$KClO_4$ 1:1	> .05	> .05	.04	.03
Zr-Ni Alloy-$KClO_4$-PbO_2 5:10:2	> .05	.04	.05	.04
Zr-Ni Alloy-$KClO_4$-PbO_2 5:10:1	> .05	.05	.05	> .04
Zr-Ni Alloy-$KClO_4$-PbO_2 10:10:2	> .05	> .05	> .05	> .05
B(82%)-$NaNO_3$ 1:1	> .05	.01		
Zr-Ni Alloy-$KClO_4$ 1:1	> .05			
Zr-Ni Alloy-$KClO_4$ 1:2	x		x	x
Zr-Ni Alloy-$KClO_4$ 1:3	x			
Black Powder 3FG	.32	.50	.50	.31

X The experimental mixture did not ignite

TABLE XVII

Minimum Charge Required for Ignition with Styphnate-Buttered Primers

Composition	I	S	E
Mg - $KClO_4$ 1:2	0.1g	0.1g	0.05g
Mg - $KClO_4$ 1:3	0.1	0.1	
Zr-Ni Alloy $KClO_4$ 1:2	0.1	0.2	0.1
Zr-Ni Alloy $KClO_4$ 1:3	0.1	0.2	
Zr(100-200) - $KClO_4$ 1:2	0.1		
Zr(200-325) - $KClO_4$ 1:1	0.1	0.2	0.2
Zr-$KClO_4$-PbO_2 10:10:2	0.1	0.2	0.2
B-$KClO_4$ 1:3	0.1	0.2	0.1
B-$KClO_4$ 1:4	0.1	0.2	
B-$KClO_4$ 1:5	0.1	0.2	0.1
Al-$KClO_4$ 1:2	0.2	0.1	
Al-$KClO_4$ 1:3	0.2	0.2	
Al-$KClO_4$ 2:1	0.2	0.2	
Ti-$KClO_4$ 1:2	0.2	0.2	
Ti-$KClO_4$ 1:3	0.2	0.2	
Zr-Ni Alloy-$KClO_4$-PbO_2 5:10:1	0.2	0.2	0.2
Zr-Ni Alloy-$KClO_4$-PbO_2 5:10:2	0.2	0.2	0.2
Zr-Ni Alloy $KClO_4$ 1:1	0.2	0.2	
Zr-$KClO_4$-PbO_2 10:10:1	0.2	0.2	
Zr(100-200)-$KClO_4$ 1:1	0.2		
Zr(200-325)-$KClO_4$ 1:2	0.2		
B(82%)-$NaNO_3$ 1:1	0.2	0.2	
B-$KClO_4$ 1:1	0.2	0.2	
B-$KClO_4$ 1:2	0.2	0.2	
Mg-$KClO_4$ 1:1	0.3	0.1	
Mg-$KClO_4$ 2:1	0.3	0.2	
Mg-$KClO_4$ 3:1	0.3	0.2	
Al-$KClO_4$ 1:1	0.3	0.2	
Zr-$KClO_4$-PbO_2 10:10:10	0.3	0.2	
Zr(100-200)-$KClO_4$ 2:1	0.3		
Zr(100-200)-$KClO_4$ 1:3	0.3		
Zr(200-325)-$KClO_4$ 1:3	0.3		
B-$NaNO_3$ 1:1	0.3	0.1	
B-S-KNO_3 15:7:75	0.3	0.3	
B-$KClO_4$ 2:1	0.3		
Black Powder 3FG	0.4	0.7	.41
Al-$KClO_4$ 3:1	0.4		
Ti-$KClO_4$ 1:1	0.4	0.2	
Ti-$KClO_4$ 5:1	0.4	0.3	
Zr(100-200)-$NaNO_3$ 3:1	0.4		
Zr(100-200)-$NaNO_3$ 2:1	0.4		
Zr(100-200)-$NaNO_3$ 1:2	0.4		
Zr(100-200)-$KClO_4$ 3:1	0.4		

TABLE XVII (cont)

Composition	I	S
Zr(200-325)-$KClO_4$ 2:1	0.4	
B-$KClO_4$ 3:1	0.4	
Ti-PbO_2 1:1	0.4	
Ti-$KClO_4$ 3:1	0.4	
Ti-$KClO_4$ 2:1	0.4	
Zr-Ti-Fe_2O_3 17:33:50	0.4	0.4
Zr-Ni Alloy-$KClO_4$ 3:1	0.4	
Zr-Ni Alloy-$KClO_4$ 2:1	0.4	
Zr(200-325)-$KClO_4$ 3:1	0.4	
Zr(100-200)-$NaNO_3$ 1:1	0.4	
Ti-$NaNO_3$ 4:1	0.4	0.4
Ti-$NaNO_3$ 3:1	0.4	
Ti-$NaNO_3$ 2:1	0.4	
Ti-$NaNO_3$ 1:1	0.4	
Ti-$NaNO_3$ 1:2	x	
Ti-$NaNO_3$ 1:3	x	
Zr(100-200)-$NaNO_3$ 1:3	x	

x = the experimental mixture did not ignite.

TABLE XVIII

Impact Sensitivity Test Results

Composition	50% Firing Height $\bar{X}$ (inches)	Standard Deviation
Black Powder	> 25	
$Mg-KClO_4$ (1:2)	16.24	3.68
$B-KClO_4$ (1:3)	7.4	0.78
$B-KClO_4$ (1:5)	7.9	1.79
$B-KClO_4$ (1:4)	9.2	0.72
$Zr-KClO_4$ (1:1)	8.9	2.46
Zr-Ni Alloy-$KClO_4$ (1:2)	19.5	2.97

TABLE XIX

Ignition Tests with SPCG-9149
Propellant at -65°F.

Weight	3 FG Black Powder	B-$KClO_4$ 1:5
1.20g	(+)	
1.00g	(-)	
.90		
.80	(-)	
.70		
.60		
.50		
.40	(-)	(+)
.30		(+)
.20		(-)
.10		(-)
.04		(-)
.02		(-)

See Table III for meaning of symbols.

TABLE XX

Compatibility of Ignition Mixtures with Primer Components
Condition: 160°F. 82% R.H. Time: 10 Weeks

Composition	Steel (Cd Plate) Tube	Brass	Paper Tube Liner
1. $MgKClO_4$ (1:2)	Corroded	Corroded	Bleached
2. $Zr.Ni-KClO_4$ (1:2)	OK	OK	Dark Brown
3. $B-KClO_4$ (1:3)	OK	OK	Bleached
4. $B-KClO_4$ (1:5)	OK	OK	Bleached
5. $Zr-KClO_4$ (1:1)	Corroded	OK	Light Brown
6. $Zr.KClO_4PbO_2$ (5:5:1)	OK	OK	Bleached
7. $B-KClO_4$ (1:4)	OK	OK	Bleached

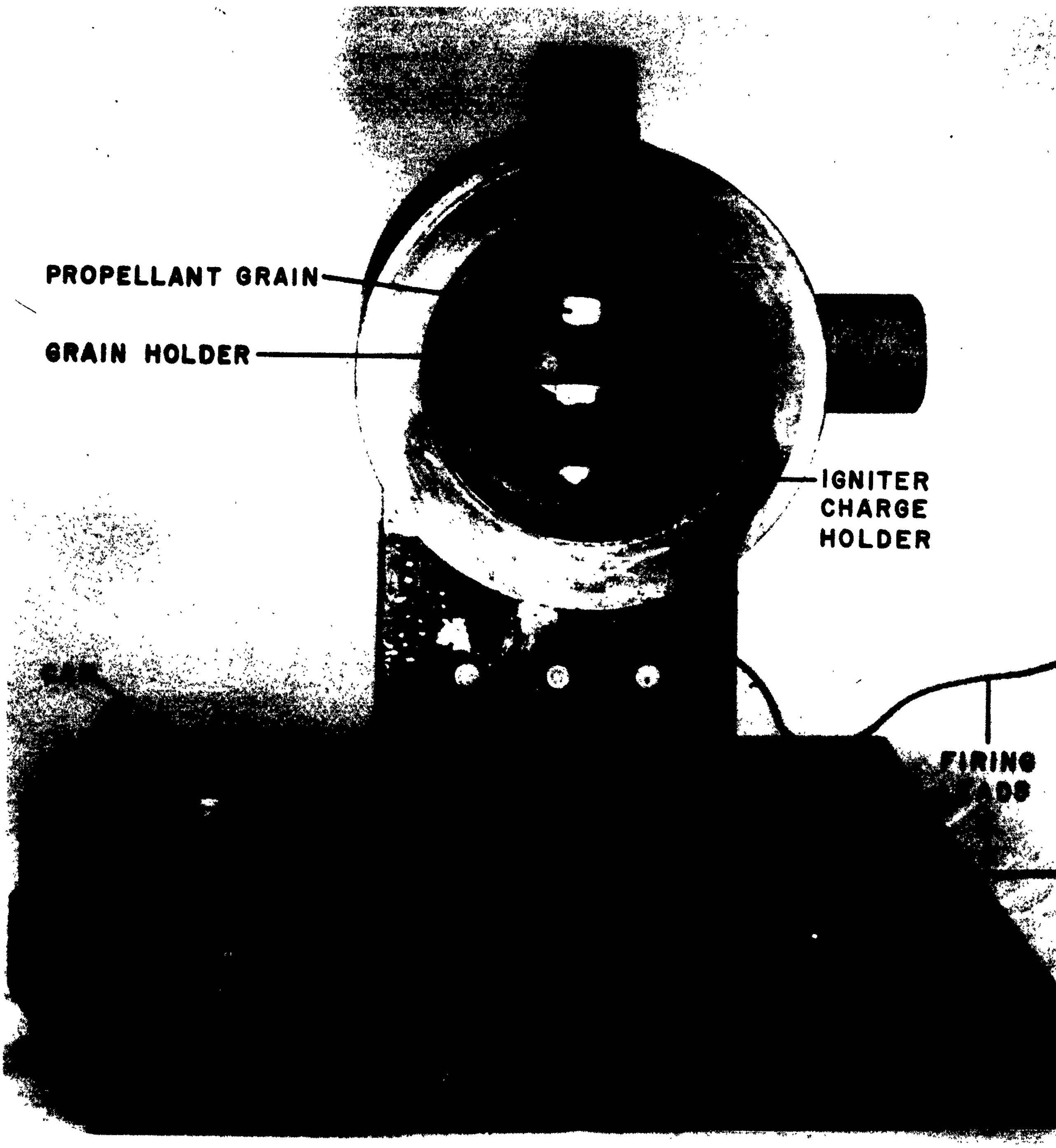

FIG. 1 PROPELLANT IGNITION BOMB